Lessons Learned From ASHRAE HQ Renovation

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George Washington once said, "We should not look back unless it is to derive useful lessons from past errors, and for the purpose of profiting by dearly bought experience." Since it has been more than five years of occupancy since ASHRAE Headquarters was renovated, this is a good time to revisit the details of the renovation project, the successes, and lessons learned. Future articles will delve deeper into the performance of the various building systems, satisfaction of building occupants, and the new data serving portal.

The original building was constructed in 1965 and was occupied by an insurance company until ASHRAE purchased it in 1980 and relocated to Atlanta from New York City.

ASHRAE did its first major renovation in 1990 by gutting the interior, updating the mechanical systems, installing a new insulated glass curtain wall system, and abating asbestos materials on the interior.

The building was extensively renovated again in 2007–08 and approximately 4,000 ft^2 (371 m^2) of space was added to the existing 30,000 ft^2 (2800 m^2) building. A significant portion of this larger building was used to create the new ASHRAE Foundation Learning Center, which allows ASHRAE to host large meetings and training sessions on-site. For comparison, the old building had six meeting rooms totaling 2,000 ft^2 (185 m^2), and the new building has triple the number of meeting rooms and four times the amount of meeting space.

The building is unique in that it contains three mechanical systems for heating, cooling and ventilation:

1. Dedicated outdoor air system (DOAS) for first and second floor ventilation;
2. Variable refrigerant flow (VRF) system with heat recovery for first floor heating and cooling; and
3. Ground source heat pump (GSHP) system for second floor heating and cooling.

LESSONS LEARNED

Living Lab

The reason for having three mechanical systems was to achieve the goal of creating a "Living Lab" for ongoing research by the Society and its members. More than

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The green roof of the Learning Center consists of three types of sedum and one ice plant that each bloom multiple times per year. The weather station is connected to the BAS and measures min./max. dry bulb air temp, RH, dew point, solar radiation, hours of sun, net radiation, barometric pressure, min./max. wind speed, wind direction, gusts, gust directions, and CO_2.

Renovation Quick Facts

92% of building structure/shell retained

91% of construction waste was diverted from landfills and recycled (2,200 tons)

22% of the total materials cost for the project came from recycled content

25% of the total materials cost for the project came from regionally supplied materials (extracted and manufactured within 500 miles from building site)

Abated remaining asbestos on-site in exterior building soffit paneling

LEED New Construction (NC) 2.2 rated Platinum building: 55 points attempted; 54 points earned; 69 possible points

Energy Star-Labeled Building in 2010, and 2012

Prior to Renovation (2007) Energy Star Score: 35; Site EUI: 79 kBtu/ft^2·yr (908 MJ/m^2·yr)

After Renovation (2012) Energy Star Score: 95; Site EUI: 38 kBtu/ft^2·yr (437 MJ/m^2·yr)

52% EUI reduction between 2007 and 2012

1,300 points are monitored and stored on the systems and spaces in this building. The stored and real-time data are then made available to our members around the world via Internet. Only a small group of building owners would allow their building to be used in such a fashion.

ASHRAE hopes to learn more about the long-term operation, maintenance and performance of buildings with the various types of systems used throughout this project. We also hope to link to similar data from other high performance buildings around the world so that our website can someday serve as a Web portal to this type of data.

Lesson Learned A need was identified through this project for developing a standard naming convention for data points so that such information can be easily used across all projects and understood by various parties.

First Floor System

The first floor is conditioned for heating and cooling using a variable refrigerant flow (VRF) system with heat recovery, which consists of five inverter driven, outdoor DX heat pumps, three ductless fan coil units, and 22 ducted fan coil units operating on HFC-410A refrigerant (system capacity 28 tons [98 kW] total). Unlike traditional AC systems, this system automatically adjusts the compressor speed and the flow of refrigerant in the system to automatically meet changes in the indoor load, reducing energy consumption. It can automatically reroute refrigerant from one zone that is in cooling mode to another zone that requires heat, bypassing the rooftop DX heat pump and avoiding its energy consumption (heat recovery).

Lessons Learned The VRF and building automation system (BAS) manufacturers had never worked together before. As a result, the control interface was challenging, and the interface may not be fully optimized to reflect the true performance of the VRF system. It would be interesting to see how the VRF system performs on its own built-in controls for scheduling, etc., without the interface to the BAS.

The refrigerant lines for the VRF units in the new ASHRAE Foundation Learning Center initially crossed a means of egress hallway. To comply with the then current version of ASHRAE Standard 15[1] (Section 8.10.2, Location of Refrigerant Piping) (similar requirements exist in the Uniform Mechanical Code and International Mechanical Code), the hall crossing had to be rerouted to the roof level. This issue highlighted a difference between ASHRAE Standard 15 and some international refrigerant safety standards, suggesting discussion was needed to better harmonize these standards.

Second Floor System

The second floor and north stairwell are conditioned for heating and cooling using 12 ceiling-mounted

The ASHRAE Foundation Learning Center was added to the building to provide ASHRAE enough space to host large meetings and training sessions on-site.

ducted, 17.45-21.07 EER, ground source heat pumps (GSHP) with a two-stage scroll compressor, and two-speed fan; two non-ducted console heat pumps for the north stairwell; a geothermal field of 12, 400 ft (122 m) deep wells, and a closed-loop piping system that circulates water (no glycol) between the building and the wells (system capacity 32 tons [113 kW] total). Average ground temperature assumed for design was 63°F (17°C).

Lessons Learned Site soil conductivity tests resulted in two additional wells being drilled to expand the original 10-well system design. As a result, the well field is able to keep up with the second floor heating and cooling loads year-round without any supplemental heating or cooling equipment beyond that supplied by the GSHP system.

The differential pressure setpoint for the closed loop was initially set at 20 psi (138 kPa) via hand calculations. Through trial and error, we found that we were able to reduce this setting to as low as 12 psi (83 kPa) before the heat pump located furthest from the pump (north stairwell console unit) dropped out, which allows pump energy consumption in the system to be reduced. The final setting was 15 psi (103 kPa) to ensure we received adequate flow to all heat pumps, which is consistent with the design engineer's original estimate of a 15 psi to 20 psi (103 kPa to 138 kPa) setpoint range.

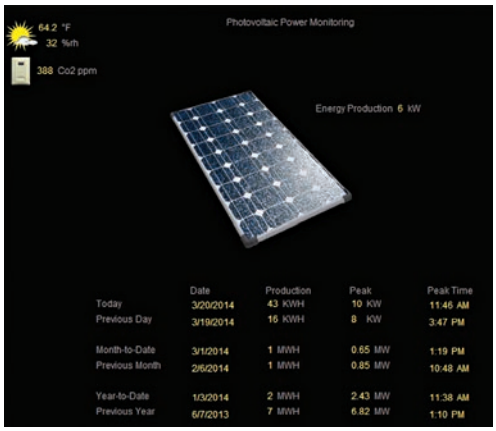
Ventilation System

A dedicated outdoor air system (DOAS) provides 6,000 cfm (2832 L/s) outdoor air at 55°F (12.8°C) supply air

Learning Center conference rooms are one of the few spaces that lack outdoor views.

temperature with 46°F (7.8°C) dew point, providing 40 tons (141 kW) of cooling and 250 MBH (73 MW) heating. It uses dual stage air-to-air heat recovery with Type 1 desiccant wheel and dehumidification with Type 3 desiccant wheel, variable speed outdoor air and exhaust air fans, six staged packaged air-cooled DX condensing units and an air-cleaning system that uses active-field technology to polarize both filter media fibers and airborne particles. The polarized particles are drawn to the fibers of the media and other particles. This process brings about a deep cleaning of the air, a near MERV 13 filter performance level, and a longer service by loading the filter through its full depth and not just on the upstream face as with passive filters.

Air is distributed throughout the building using a system of 24 supply VAV boxes and two exhaust VAV boxes, which are all connected to the DOAS. The 40 tons (141



A donated 20 kW photovoltaic (PV) solar panel array mounted on the roof produces electricity during daylight hours and feeds this energy into the utility grid upstream of the building meter. It is estimated that approximately 8% of the building's annual energy consumption can be offset by the array when all four inverters are operating properly. The array consists of a total of 120 panels, which generate a 600 V dc voltage. Four dc/ac inverters convert this voltage into a 208 ac voltage, which is fed to the utility grid.

kW) of capacity for the DOAS when combined with the 28 tons (98 kW) for the VRF and 32 tons (113 kW) for the GSHP gives us a total of 100 tons (352 kW) of capacity. For comparison, the previous building was cooled by a 70 ton (246 kW) air-cooled chiller.

Lessons Learned Roof deflections due to rooftop equipment loads (if not properly accounted for with build-ups and tapered insulation blocking under the roof membrane material) will create low spots for water and debris to collect near equipment and, more problematically, next to the building's outdoor air intake.

Data from the Living Lab helped to identify that the staged sequencing of the six condenser compressors that support the DOAS air handler was not optimized (sawtooth behavior). By switching out the supply air temperature sensor for an averaging multipoint temperature sensor in the air handler and adjusting some control parameters, we were able to significantly reduce, but not completely resolve, this issue.

Indoor Air Quality

The building uses low-emitting materials, such as furnishings, paint, linoleum, and carpet, throughout to reduce indoor air contaminants that are odorous, irritating or harmful to the comfort and well-being of occupants. Based on the reduction of volatile chemicals, ASHRAE was able to save time, money, and energy by performing the IAQ test option to achieve LEED NC 2.2 credit IEQ 3.2, rather than using the "flush out" option.

Flush out is very energy-intensive, requiring 14,000 ft^3/ft^2 (4268 m^3/m^2) of outdoor air that is heated and/or cooled to 60°F (15.5°C), 60% RH before the building can be occupied. Also, the permanent ventilation airflows in the building exceed minimums of ASHRAE Standard 62.1-2004 by 30%, allowing the award of LEED credit IEQ 2 for increased ventilation.

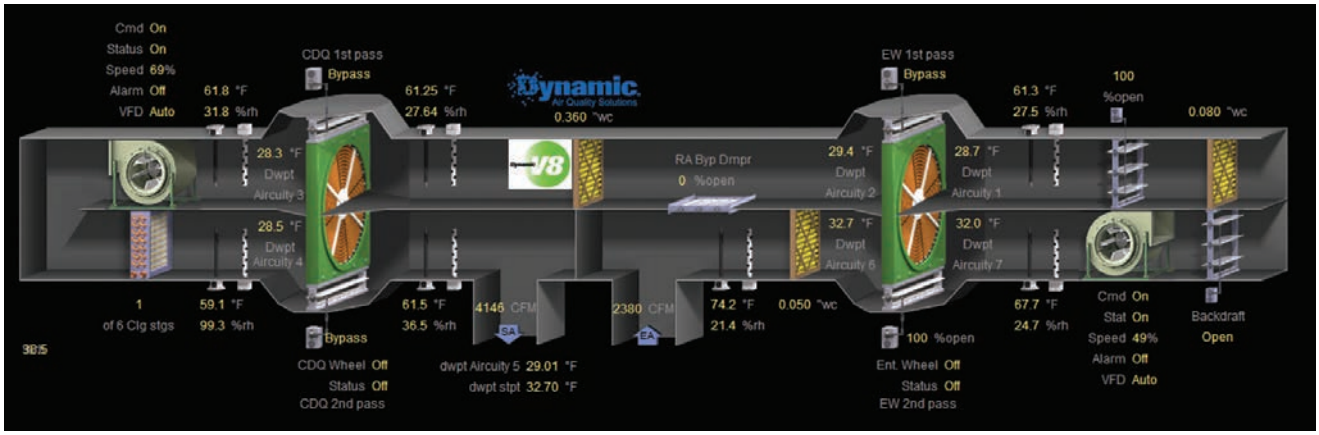
Further, in spaces with high variable occupancy (e.g., ASHRAE Foundation Learning Center), ventilation airflows are modulated based on CO_2 to reduce outdoor air rates during partial occupancy.

The capability to closely monitor/assess the indoor spaces of the building through the Living Laboratory, occupant surveys, and other measures allows the potential for better understanding the relationship between ventilation rates, occupant comfort, productivity, and energy consumption in future studies.

Lessons Learned Occupant surveys were conducted in 2005 (prior to renovation), 2010, and 2013. Air quality satisfaction increased from 26% in 2005 to 77% in 2010 and 70% in 2013. Cleanliness and maintenance satisfaction increased from 21% in 2005 to 83% in 2010 and 79% in 2013. The small drop in satisfaction between 2010 and 2013 could be due, in part, to changes in staff between the two surveys.

A donated air-monitoring system tracks temperature (dry bulb and dew point), relative humidity, enthalpy, carbon dioxide, total volatile organic compounds (TVOCs), and particulates (PM 2.5) in 24 room locations, two outdoor air locations and seven locations in the DOAS unit (sensors are recalibrated every six months). Similar sensors are also provided as part of the BAS and are compared with the readings.

The donated air system has allowed us to monitor more areas of the building, which has been useful in troubleshooting occupant comfort complaints. For



A DOAS provides 6,000 cfm outdoor air at 55°F supply air temperature with 46°F dew point, providing 40 tons of cooling and 250 MBH heating.

example, dew-point temperature readings inside the air handler were found to be more accurate using sensors from this donated system. Since many of the inside sensors are also located adjacent to BAS sensors, it is now much easier to identify sensors that have gone bad or are out of calibration.

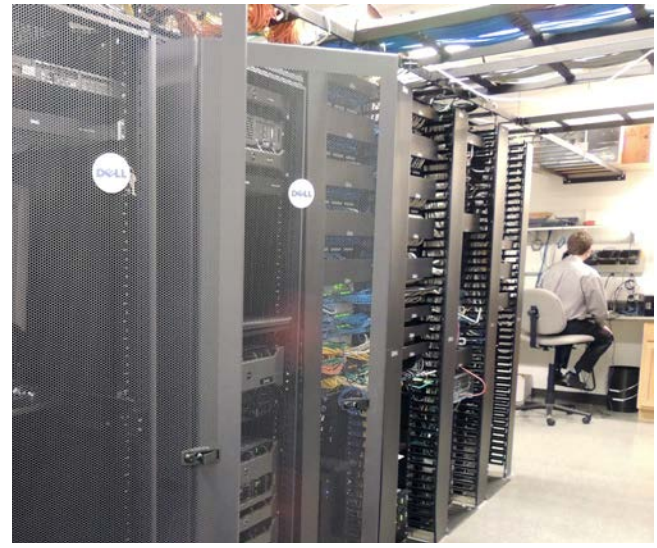
MERV 13 filter modules are installed in the DOAS unit and on all VRF fan coil units and GSHPs.

Somewhat unexpectedly to us, but not the manufacturer, all of the original filter media, except for the media servicing the building's vestibule entrance, is still in place after five years of operation. The media in the vestibule was replaced early at the request of the manufacturer to provide them with a sample for marketing purposes about a year ago. Differential pressures (DP) across all filters are still low (current: DOAS: 0.38 in. w.g., highest VRF FCU: 0.100 in. w.g., highest GSHP: 0.244 in. w.g.) and a change-out is not required yet (replacement level: DOAS: 0.53 in. w.g., highest VRF FCU: 0.418 in. w.g., highest GSHP: 0.418 in. w.g.).

As of February 2014, the filter modules that service the building's vestibule entrance (equipped with a walk-off mat) and second floor main landing at the top of stairs have the highest DP readings right now at 0.100 and 0.244, respectively, as one would expect. In addition, since anything on the filter media is electrically bonded to the fibers, we have not seen a need yet to change out the media due to microbiological growth on the media because we have not seen increasing VOC levels in the building with the donated air monitoring system.

Thermal Comfort

Occupant surveys showed thermal comfort increased from 18% in 2005 to 33% in 2010 and 36% in 2013.



Virtualized servers reduced server footprint by 80%, emptying one rack entirely.

Standard heating setpoint is 68°F (20°C) and 74°F (23.3°C) for cooling. Staff is able to adjust zone setpoint ±3°F (1.7°C) through local controls.

Lesson Learned Widely differing thermal comfort levels for individuals sitting adjacent to each other in an open office arrangement does not lend itself well to resolution. As a result, it may be better to strive instead for consistent temperatures in the zone and allow the opposing individuals to adjust accordingly via their clothing selections for in the office.

On-site Power Generation

A donated 20 kW photovoltaic (PV) solar panel array mounted on the roof produces electricity during daylight hours and feeds this energy into the utility grid upstream of the building meter. It is estimated that approximately 8% of the building's annual energy consumption can be offset by the array when all four

(Left) Slot diffusers run along the perimeter ceiling. (Right) Air quality satisfaction increased from 26% in 2005 to 77% in 2010 and 70% in 2013.

inverters are operating properly. The array consists of a total of 120 panels, which generate a 600 V dc voltage. Four dc/ac inverters convert this voltage into a 208 ac voltage, which is fed to the utility grid.

Lessons Learned Increasingly, one or another of the system's four power inverters routinely goes off-line and must be reset manually, which requires climbing a ladder to the roof level. Each such outage cuts capacity by 25%.

The original installer has tried to correct the product defect with no success. Also, the specific inverter manufacturer has since been dropped by the PV system supplier. Once a new, more reliable, set of inverters is identified and installed, the operating status of each inverter should be closely monitored for similar faults and annunciated through the building automation system.

We also learned that the installer did not install a shield over the inverters to prevent overheating caused by solar heat gain, especially in the summer, as required in the manufacturer's installation manual.

Power Monitoring

Electrical loads were extensively isolated by use and submetered on separate panels to better understand how energy is used in the building.

Submetered Panels: first floor lighting; first floor plug loads; first floor mechanical; second floor lighting; second floor plug loads; second floor mechanical; DOAS; PV array; computer room (server load + cooling load); outdoor lighting; and water heating.

Lessons Learned Commissioning proved to be invaluable to the project. We learned, for example, that the six condensers that are part of the DOAS system were not included on the DOAS submetered electrical panel initially.

In 2009, we were pleasantly surprised that our plug loads and computer room electrical loads dropped 20% to 30% after we switched out leased desktop computers for a thin-client system, and replaced server racks for blade-type servers. Also, after these changes, the two ceiling-mounted VRF units that cool the computer room were each fully able to keep up with the load in the room on even the hottest summer days.

Water Consumption

Calculated annual flush fixture water consumption has been reduced by 52.3% for bathrooms and flush and flow water consumption by 46.3% overall for the building in comparison to a similar-size office building. This reduction was achieved by using low-flow toilets, waterless urinals, plus reconfigured landscaping to eliminate the need for irrigation. Landscape water savings were achieved by re-landscaping the majority of the site with plant species that are native or naturalized to the piedmont of Georgia. Microclimatic conditions throughout the site were carefully analyzed to select species that are specifically adapted to the varying conditions. When compared with the old building's metered water use, the savings are even greater, with an estimated 67% reduction in annual water consumption.

Lesson Learned Automatic toilet flush sensors, if not adjusted properly for male and female users, will waste a large amount of water due to multiple unintended flushes. Also, once the approximate change-out schedule is determined for waterless urinal cartridges, they are very effective and provide acceptable odor control. To date, no piping system issues have been identified given the lack of water flow in the urinals and reduced flush rates.

During the 2008 renovation, ASHRAE switched from a 50/50 mix of private offices and cubicles to 95% cubicles in an open office layout. Minimizing the number of perimeter offices and using glass-walled cubicles maximizes the daylight outdoor views entering the space.

Lighting

Interior lighting power density is 19% lower than ASHRAE/IESNA Standard 90.1-2004. Photocells, occupancy sensors, and occupancy schedule are used to control lighting use. A change-out to LED lights in some locations also is being considered as an additional energy savings improvement.

Lessons Learned We have learned that on/off light ballasts are not suitable for daylighting and that dimmable ballasts are required due to scattered cloud conditions. Adjustments to the photocell hysteresis were not sufficient to eliminate complaints from staff.

We also learned that a single controller in a first floor panel controls all the lighting breakers for the building

and parking lot lights that are on a schedule. When this controller fails, all of the lights it controls will stay on 24/7, but the BAS lighting control display falsely reports that all lights are off as scheduled. The false report made it difficult to detect the problem immediately. The lead time for the replacement controller was lengthy (six to eight weeks). So, in the future, it may be useful to repair and keep the old controller as a spare (along with its tested and verified program) so that repairs can be implemented more quickly.

The differential pressure setpoint for the geothermal closed loop was initially set at 20 psi via hand calculations. Through trial and error, the final setpoint was lowered to 15 psi.

Parking lot lighting power density is currently 21% lower than Standard 90.1-2004. This was achieved by use of metal halide (MH) high intensity discharge (HID) lamps and aluminum reflectors on the lighting poles. Further reductions in parking lot lighting power consumption may be possible in the future by changing to LED fixtures now offered by the same manufacturer.

Interior Features

Acoustics. During the 2008 renovation, ASHRAE switched from a 50/50 mix of private offices and cubicles to 95% cubicles in an open office layout. As a result, steps were taken through finish material selections, insulation, small enclosed meeting spaces (hoteling spaces), seals, and sound masking to isolate objectionable noise sources. This also included using a white noise device in the open office areas.

Lessons Learned With respect to acoustics, a large majority of staff members are "not loving" our new communal seating arrangement. Conversations travel long distances in an open office floor plan, so for extended conversations staff has had to adjust their habits and make greater use of hoteling spaces (small

Photocells, occupancy sensors, and occupancy schedule are used to control lighting use. A change-out to LED lights in some locations is being considered.

meeting rooms for up to four occupants) and conference rooms, etc., for extended conversations. Some staff members have also found it necessary to use noise canceling headphones and other devices to block noise distractions when working in their cubicle. Staff dissatisfaction remains high on this issue. Occupant surveys showed Acoustic Quality Satisfaction decreased from 33% in 2005 to 29% in 2010 and 20% in 2013.

Outside Views. On a more positive note, outside views are now provided to 98% of the regularly occupied spaces. We also have views from nearly all of our conference rooms, libraries, and hoteling spaces. The spaces that make up the 2% without views include the offices of the human resource staff. Their job functions require greater visual and acoustic privacy.

This is a great improvement in visual access compared to the old building layout, in which private offices ringed the entire perimeter. The core had no views to the outside,

Prime parking spaces allocated to fuel efficient vehicles and to staff who carpool.

and also required 100% on artificial lighting. In spite of these improvements, LEED credit IEQ 8.2 (daylight & views: views for 90% of spaces) was denied because the ASHRAE Foundation Learning Center conference rooms (classrooms) lack outdoor views.

Reused, Refinished Materials. The original fire sprinkler piping and most of the glazing were reused throughout the building for this renovation. New bathroom walls were clad with refinished marble panels salvaged from a building in downtown Atlanta prior to demolition. These measures helped save significant amounts of money and resources for the project.

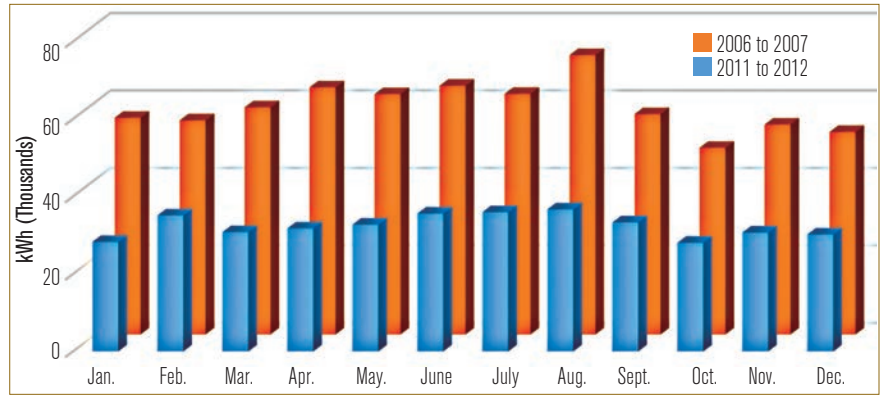
Recycling. ASHRAE site recycling program collects paper, toner cartridges, glass, plastic, cardboard, batteries, and metal, helping to conserve valuable materials and energy for future generations.

Lesson Learned Built-in recycling stations installed in the building are not required today because most local recycling companies have gone to a single stream process that allows for automated separation of fully commingled materials at the recycling facility.

Site Features

Bio-retention Ponds. Site runoff amount has been reduced by 31% and the rate of runoff by 30%. Runoff water is naturally filtered of pollutants through a bioswale, which gradually releases water back into the buried detention pipe manifold, and eventually the city storm-water system to prevent overload. The bioswale is designed to trap 80% of the total suspended solids in site runoff. The amount of vegetated open space was increased by 41% above local code minimum requirement to conserve valuable water, reduce runoff, reduce heat island effects, and help provide a more attractive site.

Lesson Learned Local county inspectors were not familiar enough with bio-retention ponds to be confident they would work long term when they were proposed in 2007. As a result, they also required the installation of a costly and redundant culvert pipe manifold system as a back-up to the bio-retention ponds for site runoff.



Electrical energy end use for ASHRAE headquarters.

Heat Island Reduction. Reduced heat island effect from the roof and parking lot is achieved by using a cool white reflective roof membrane with a solar reflectance index (SRI) of 78 and a protective crust over 50% of the parking lot pavement with a SRI of 32. Another 15% of the parking lot is shaded by trees. The parking coating has an expected life expectancy of 25+ years, but we are conducting a side-by-side comparison to verify this claim.

Lesson Learned The white roof membrane requires regular cleaning to maintain SRI. And to maintain warranty, the manufacturer requires inspections to check for potential membrane penetrations or leaks.

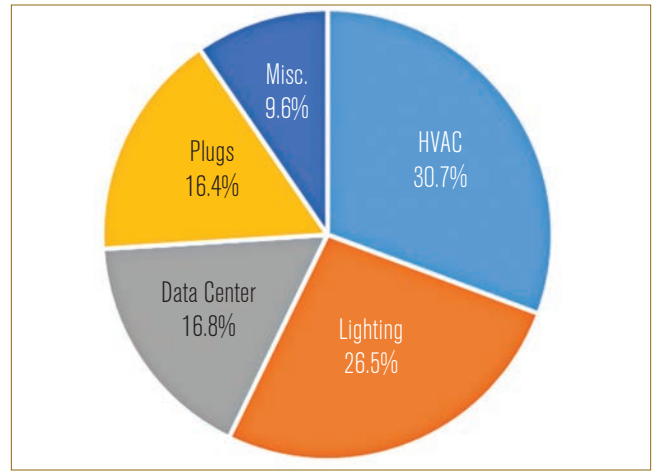
The parking lot coating was installed after we reoccupied the building and had a parking lot nearly full of cars. This required moving cars to coated sections after a few hours drying time. One disappointment has been with the touch-up material that was used by the manufacturer to fill some cracks. After a few years of operation, the touch-up material has gradually turned black and no longer blends with the original light gray coating color. Oil leaks from cars and other stains are also more prominent on the light gray coating.

Site Connectivity. Public transit access is provided within a quarter mile (0.40 km) to multiple bus routes. Staff members can take a short bus ride to or from two MARTA rail stations using this bus stop. Less than 5% of staff use public transit to get to and from work. However, an increasing number of staff carpool to work to save gas and to drive in carpool lanes on highways.

New Amenities

Parking. Prime parking spaces are allocated to fuel-efficient vehicles and staff who carpool. A bike rack has been provided for those who commute by bike to work.

Lesson Learned The specially designated parking lot spaces are not used to full capacity on a regular basis. So temporary signs were created to repurpose these spaces to provide more visitor parking during large special events. The bike rack has seen very limited use. This is most likely due to the fact that the headquarters building is located adjacent to an interstate highway, and surface streets lack designated bike lanes.



Electrical energy end use for ASHRAE headquarters.

Smoking Area. A designated smoking area is provided for staff and visitors at the back of the parking lot, at some considerable distance from the building.

Lesson Learned In the future, it would be useful to add a canopy to the smoking area to provide rain protection for employees and visitors who smoke. Visitors who attend training classes at the building commute in many cases via taxi or hotel shuttle bus and don't have access to a car when it rains as do staff smokers who tend to smoke in their cars.

Green Cleaning & Integrated Pest Management Program. ASHRAE has implemented these programs to reduce the exposure of building occupants, visitors, and maintenance personnel to potential hazardous chemical, biological, and particulate contaminants. These

adversely affect air quality, human health, building finishes, building systems and the environment. The headquarters now uses environment-friendly products, methods and equipment and uses the proper pesticides only when necessary.

Lesson Learned Excessive amounts of food spilled or dropped in the office area will eventually attract pests into the building. We have learned that source control is the key factor for keeping pests out of the office area, which reduces the frequency of deep cleaning and in turn chemical cleaners.

Since the building was renovated in 2008, more than 100 building tours have been conducted.

Shower. Shower and changing rooms are available on-site for bike commuters or staff who want to exercise during lunch breaks.

Lesson Learned There are few bike commuters on staff because of our location next to an interstate highway and surface streets that have no bike lanes. However, the changing rooms have proven useful for staff who walk during their lunch break or who change clothing for after-work activities.

Weather Monitoring Station. The weather station is connected to the BAS and measures min./max. dry bulb air temp., RH, dew point, solar radiation, hours of sun, net radiation, barometric pressure, min./max. wind speed, wind direction, gusts, gust directions, and CO_2.

Lesson Learned A lighting strike to the station in 2009–10 has plagued its performance and reliability. Since then, we have learned that the manufacturer's service network is much smaller than originally thought. There are currently no service technicians for this equipment in the metro-Atlanta area or in the State of Georgia.

Green Roof. The green roof consists of three types of sedum and one ice plant that each bloom multiple times per year. The green roof is not supposed to require irrigation once fully established, and it helps to reduce site runoff, heat gain through the roof area, and also helps to insulate meeting space from outside noise sources.

Lessons Learned In hindsight, we should have developed a system to harvest the DOAS condensate water so that it could be saved in a cistern and used when required for watering the roof. The built-in reservoir section in the green roof plant tray system is insufficient in summers, particularly during periods of drought.

We also learned the plants used for the green roof are native to the northern State of Minnesota. They have struggled to survive in the intense summer heat that we experienced during 2010, 2011, and 2012 in Georgia. It was also a challenge to find a fertilizer material to safely use on the green roof without possibly violating the roof membrane material warranty.

Building Tours

Building tours are provided with advance notice on an as-needed basis. Please contact Mike Vaughn (404-636-8400 x 1211, mvaughn@ashrae.org) to arrange a tour.

Lesson Learned Since the building was renovated in 2008, more than 100 building tours have been conducted. In hindsight, the elevator should have been designed to access the roof level so visitors—most of whom wish to see the rooftop equipment—don't have to sign a waiver of liability and climb a ladder to the rooftop level.

Conclusion

ASHRAE had the opportunity prior to the latest renovation to lease new space elsewhere or build new, but recognized that the greatest opportunity to change energy consumption in the built environment is through modification of existing buildings. By looking forward and taking the path to renovate, ASHRAE showed what can be done with a nearly 50-year-old building.

References

1. ASHRAE Standard 15-2004, *Safety Standard for Refrigeration Systems.*

2. LEED® for New Construction & Major Renovations, Version 2.2. ■